While numerous effective methodologies exist for displaying the magnitude of individual vectors, the ability to observe commonality of individual vector orientation within vector fields containing thousands of individual vectors on a surface or within a volume can be difficult to discern.

The applicant is aware of several attempts in prior art, which relate particularly to the visualisation of three-dimensional vector fields. Reference may be had by turning to Form PTO/SB/08B where references are cited thereon.

Current methodologies for indicating vector orientation consist of streamlines, hedgehogs, stream-ribbons, stream-polygons and textures maps[3]. In all these methods there are difficulties in observing the vector orientation orthogonal to the

observation surface or in selection of unique desired orientations. Figure 5 of the drawing sheets illustrates a vector grid that shows this effect. A novel texture mapping procedure is hereby disclosed that overcomes many of the shortfalls of the earlier methods.

Many applications exist for the use of an effective display of vector orientation including studies in fluidics, electromagnetic fields, finite element analysis, magneto hydrodynamics, plasma physics, astrophysics magnetic and digital elevation models (DEMs). We will present an embodiment in which the application of the present method is illustrated in the field of geophysical geomagnetic mineral exploration. It is to be recognized that this embodiment is but only one example of the usefulness of this Vector Orientation Visualization Method.

Geomagnetic surveys have many uses and are of particular interest in mineral exploration, as they may identify areas likely to contain some types of valuable deposits. They can also identify various lithologies, and provide some types of structural information.

A common method of performing such a survey is to measure the magnetic field at various points along the Earth's surface while recording the magnitude variations in the magnetic field strength. Although dip needle surveys have been used in the past, until recently, the orientation of the magnetic field was not generally measured. The magnitude of variations in the readings was primarily due to variations in the magnetic susceptibility of the constituent minerals within the rock, and to a much lesser degree, the variation of the orientation of the remanent field. Such surveys, while giving useful data, which related primarily to lithological effects, disregarded the information of the orientation of the magnetic field.

Recently, due to the introduction of tri-axial gradient magnetometer surveys, it has become possible to retrieve vector oriented gradient data. In addition, tri-axial

fluxgate total magnetometer surveys can also be used to measure the orientation of the total magnetic field vector. Tri-axial fluxgate magnetometers have also been used in along a borehole to effectively delineate the partial outline of a dipole about a ferromagnetic ore body[4].

The ability to effectively display the orientation of the magnetic vectors over a surface or within a block of rock as by borehole surveys can greatly add to the geologic understanding of the survey area and can lead to a better understanding of the location and extent of several varieties of ore deposits.

To understand the benefit of knowing the orientation of the vectors within the survey area it is important to understand the means by which variations in the orientation of the vectors can occur. After a high temperature thermal event, certain minerals in the earth will heat enough beyond their Currie Point Ne'el temperature to lose their magnetism. When the temperature lowers, these minerals regain their magnetism and will now have a thermal remanent magnetic field aligned with that of the earth at the time of going through their Currie temperature. Since the earth's magnetic field is known to change directions and flip at various times, the differently oriented remanent magnetic vectors of these remagnetized minerals can indicate spatially segregated intrusives of contemporaneous age, multiple pulsed intrusives within a similar rock type, the extent of their thermal aureoles and the presence of folds and faults. Similarly alteration due to chemical -known as chemical remanent magnetism, CRM- and pressure changes -known as piezoremanent magnetism- can result in the formation of new minerals, which will retain a remanent orientation of the earth's field orientation at that time –known as detrital remanent magnetism (DRM) caused by the quiescent sedimentation of fine magnetic material aligning with the earth's magnetic

field at the time of sedimentation.- DRM is another remnance whose variation can be used to recognize later faults and folds.

For the purpose of this embodiment a magnetic survey can be performed using either a tri-axial fluxgate magnetometer or tri-axial gradient magnetometer. The vertical gradient can also be calculated if both horizontal gradients and the total magnetic field are known. These types of surveys produce the magnitude of the magnetic field for each of the three-orthogonal directions. The data is collected for process and analysis over the survey area by establishing a two-dimensional grid over the area of interest. Measurements of the magnetic field are taken at specific points on the grid either by aircraft or by an operator on the ground working along a cut or demarked grid. . Each collection point is identified as a point on the two-dimensional grid, and will have an associated three-dimensional vector representing the magnetic field at that point. Alternatively, if the data should be collected along a borehole as a function of its distance from the collar, the location of the three-dimensional vector can be represented from the surveyed borehole information as a point in 3D space with x, y, z co-ordinates. The x,y co-ordinates can match the two dimensional grid of the surveyed area of interest mentioned earlier.

Peters Reference[1]: This reference describes a method of representing an electromagnetic vector field defined over a three-dimensional surface. A triangular grid represents the surface, and the method uses color shaded magnitude contours and directed vector lines to characterize the vector field. Referring to the Figures, it may be seen that in this reference, the direction of a vector field is represented using arrows, and the magnitude of the vector field is displayed using colors. Such visualization is suited to vector fields for which the direction changes gradually and continuously. The magnitude of the vector field can then be visually identified by the intensity of the colours used.

Therefore $X_{calibrated}$ equals X_m- $X_{basestation(time)}$ which is equal to $X_m - |X_{bavg} - X_{b(time)}|$. Values for $Y_{calibrated}$ and $Z_{calibrated}$ are calculated in a similar manner.

After the values $X_{calibrated}$, $Y_{calibrated}$ and $Z_{calibrated}$ for each measuring station have been calculated. A second step may be performed to remove the geomagnetic field vector from these values in order to obtain a residual magnetic value from the magnetic field data.

This is achieved by calculating the Earth's magnetic field using the standard International Geomagnetic Reference Field (IGRF) procedures to determine the theoretical values with respect to the area of interest at the time of the survey These theoretical values obtained may be represented as X_{igrf}, Y_{igrf} and Z_{igrf}.

The residual magnetic data values $X_{residual}$, $Y_{residual}$ and $Z_{residual}$ may then be calculated from the equations $X_{calibrated}$- X_{igrf}, $Y_{calibrated} - Y_{igrf}$, and $Z_{calibrated} - Z_{igrf}$, respectively.

After calculating the residual magnetic values, further methods known to the trade[5] may be performed which causes the induced magnetic field value to be removed from the residual magnetic data values to obtain remanent field values at the measuring stations.

In order to calculate the remanent values $X_{remanent}$, $Y_{remanent}$ and $Z_{remanent}$, the equations $X_{residual}$- $X_{induced}$, $Y_{residual} - Y_{induced}$, and $Z_{residual} - Z_{induced}$, are respectively determined. The remanent value represent the magnetic field data values were frequently acquired at the time the ferromagnetic rock forming minerals were formed or went through a Currie temperature episode of its ferromagnetic minerals. This remanent vector data can therefore allow for discrimination. After calculating either the residual or remanent data these x, y, z Cartesian values are transformed to mathematical spherical co-ordinates using the following equations:

r_{math} = squareroot($X^2 + Y^2 + Z^2$) where r is the radius of the unit sphere used to determine spherical co-ordinates;

Θ(theta)$_{math}$ = arctan (Y/ X) where theta represents the azimuth angle, which is measured from the positive x-axis toward the positive y-axis theta and is a value between 0° and 360°;

Φ(phi)$_{math}$ = arctan ((squareroot($X^2 + Y^2$)/ Z) where phi is the angle measured from the vertical positive z axis counterclockwise toward the x,y plane and is a value between 0°to 180°.

These mathematical spherical co-ordinates are illustrated clearly in Figure 4.

The mathematical spherical co-ordinates of the magnetic vector at each measuring station may then be represented by (r_{math}, Θ_{math}, Φ_{math}).

A conversion of the mathematical spherical co-ordinates (r_{math}, Θ_{math}, Φ_{math}) is then translated into the geological co-ordinates (r_g, Θ_g, Φ_g) by the following equation: (r_g, Θ_g, Φ_g) = [(r_{math}), (Θ_{math} – 270), (90- Φ_{math})] as clearly illustrated in Figure 4a. These values are tabled in Figure 8.

After calculating the geological spherical co-ordinates for each measuring station, a unique colour based legend may be determined by assigning colour or patterns to the spherical co-ordinates. Several colour models or notations exist which have direct symmetry with respect to spherical co-ordinates such as red, green, blue (RGB); Commission Internationale de l'Eclairage (CIE), hue, saturation, value (HSV); hue, saturation, luminance (HSL), CIE XYZ, YIQ, Munsell, TekHVC, CIE LUV etc… The last three of these models allow for a more continuous perception of colour to the human eye. Although any of these colour models may be used in the preparation of a suitable colour model via the proper mathematical translation. In this embodiment a modified spherical

the aircraft flies over a prescribed calculated grid lines to record the magnetic vector information at regular time intervals corresponding to a specified distance given the airspeed flown. In order to ensure that the aircraft follows the calculated grid lines, a GPS is to be used to guide the aircraft. In this aerial data collection no baseline or ground demarcation of lines is required.

The magnetic field vector information is collected via instruments on the aircraft as they fly over the measuring station and stored on record keeping equipment, such as a data logger, located on the aircraft. Calibration and corrections to the data are carried out later after each day's flying.

An example of the 3D versatility of this colour coded vector orientation methodology is also given in Figure 12 where the method illustrates vector orientation sample points collected along a borehole within a given volume by the use of coloured voxels.